

Sunlight, Sea Ice, and the Ice Albedo Feedback in a Changing Arctic Sea Ice Cover

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LONG-TERM GOALS

The overarching goal of this work is to develop a quantitative understanding of the partitioning of solar radiation of the Arctic sea ice cover and its impact on the heat and mass balance of the ice and upper ocean. Particular emphasis will be placed on the Chukchi and Beaufort Seas, where there have been large changes in ice conditions in recent years.

OBJECTIVES

1. Synthesize relevant data from reanalysis products, satellite observations, previous field campaigns, and the ongoing Arctic Observing Network.
2. Calculate the partitioning of spectral solar radiation between reflection to the atmosphere, absorption within the ice, and transmission to the ocean.
3. Determine the relative impact on solar partitioning of changes in i) incident solar radiation, ii) ice concentration, iii) ice age, and iv) onset dates of melt and freezeup.
4. Assess the magnitude of the contribution from ice-albedo feedback to the observed decrease of sea ice in the Chukchi and Beaufort Seas.
5. Relate solar heat input to the ice and ocean to surface, bottom, lateral, and internal melting of the ice cover.
6. Determine spatial distribution and temporal evolution of solar heat absorbed in the upper ocean.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 30 SEP 2013		2. REPORT TYPE		3. DATES COVERED 00-00-2013 to 00-00-2013	
4. TITLE AND SUBTITLE Sunlight, Sea Ice, and the Ice Albedo Feedback in a Changing Arctic Sea Ice Cover				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL), 72 Lyme Road, Hanover, NH, 03755				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 3	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

7. Transfer results from this study to the sea ice prediction and modeling community to improve the treatment of solar radiation and the ice-albedo feedback. This transfer will take the form of publications and direct input to parameterization development.

APPROACH

The central element of our approach is synthesis. We will synthesize remote sensing observations, reanalysis products, field observations, autonomous in situ observations, and process models. Our study area is the Arctic Ocean and surrounding seas, with particular emphasis on the Chukchi and Beaufort Seas. Some of the largest changes to the sea ice cover are occurring in the Chukchi and Beaufort where there are many ongoing research efforts affording opportunities for synergy and collaboration. The analysis will be done on a 25 x 25 km equal area scalable grid. The use of this grid will facilitate integration and synthesis of observations from different datasets and the export of our results to potential users. This work builds on earlier studies of the impact on albedo evolution of ice concentration and melt and freezeup onset dates. This effort will expand on previous work by i) examining the impact of the shift from multiyear to seasonal ice; ii) determining heat absorbed in the ice, transmitted through the ice and deposited into the ocean; and iii) taking a regional focus with extensive data assimilation.

This work is directed at improving our ability to predict the state of the ice cover in the Chukchi and Beaufort Seas over scales from weeks to years to decades. Integration, synthesis, and collaboration are key elements of this project. We will integrate our efforts with ongoing research in the Chukchi and Beaufort Seas including the ONR-DRI on Emerging Dynamics of the Marginal Ice Zone, the Sea Ice Outlook, the Arctic Observing Network projects and the NASA-sponsored projects Icebridge and Icescape (Impacts of Climate change on the Eco-Systems and Chemistry of the Arctic Pacific Environment). These projects have generated extensive datasets on ice conditions and ice mass balance, biological, and oceanographic conditions in the Chukchi and Beaufort Seas.

WORK COMPLETED

This year we focused on assembling a dataset and developing the theoretical framework needed to examine solar partitioning. We have compiled information on incident solar radiation, ice concentration, ice type, and melt and freezeup onset dates on a 25 x 25 km equal area scalable grid. We have daily values of these parameters from 1980 to 2012. We have also developed software to compute solar input into the ocean and ice.

Additionally, we have used three data sources to build a quantitative understanding of light propagation through first-year Arctic sea ice. These data sources include:

1. Field measurements made during the Icescape campaign by Perovich and Light
2. Field measurements made on high salinity first-year ice off the coast of Svalbard by Light and Norwegian collaborators
3. Laboratory measurements made by B. Light on cold first-year sea ice returned from Barrow AK from the BROMEX program

The interpretation of these three data sources has been yielding new insight on the evolution of optical properties of first year Arctic sea ice.

RESULTS

Decreases in ice concentration substantially increase solar heat input to the ocean. Earlier dates of melt onset reduce ice albedo during a period when incident solar irradiance is large increasing solar heat input to the ice. Seasonal sea ice typically has a smaller albedo than perennial ice throughout the melt season. Thus, the observed shift to a seasonal ice cover causes greater solar heat input to the ice and more melting thereby accelerating ice decay. Thinner ice results in greater transmission of solar heat to the upper ocean, where it contributes to bottom melting, lateral melting, and warming of the water. All of these changes enhance the amount of solar energy deposited in the ice ocean system, and increasing ice melt. We have determined that the conditions in spring strongly influence solar heat input as does ice concentration and the amount of first year ice. Events in the fall only have a modest impact on solar partitioning.

Additionally, we are beginning to understand how to appropriately model the transmission of light through first-year sea ice. We have developed an optical model for such ice, that is being applied to sea ice radiative transfer modeling.

IMPACT/APPLICATIONS

Our findings are clarifying the differences in optical behavior between first year and multiyear ice and ascertaining the effect of changes in seasonal timing of melt and freezeup.

RELATED PROJECTS

Our work is closely integrated with several other Office of Naval Research projects. Our radiative transfer modeling requires information on sea ice morphology including ice concentration, pond fraction, melt state, snow depth, and ice thickness. We are working with K. Golden on melt pond statistics, J. Richter-Menge on floe size distribution, and C. Polashenski on remote sensing products for sea ice. We are making use of modeled ice thickness fields from the Pan-Arctic Ice-Ocean Modeling and Assimilation System (PIOMAS). We are also integrating our efforts with ongoing research in the Chukchi and Beaufort Seas including the ONR-DRI on Emerging Dynamics of the Marginal Ice Zone, the Sea Ice Outlook, the Arctic Observing Network projects and the NASA-sponsored projects Icebridge and Icescape (Impacts of Climate change on the Eco-Systems and Chemistry of the Arctic Pacific Environment).

HONORS/AWARDS/PRIZES

Don Perovich, EREDC-CRREL, Fellow, American Geophysical Union

Don Perovich, ERDC-CRREL, Commander's Award for Civilian Service, Partnership in Education Award, US Army Corps of Engineers.